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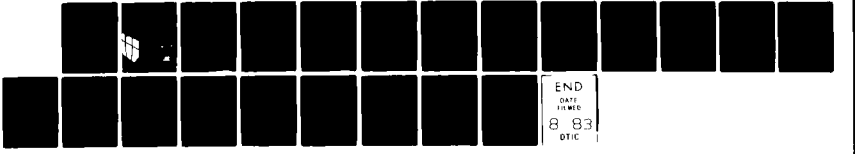

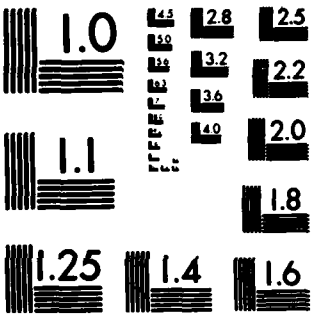

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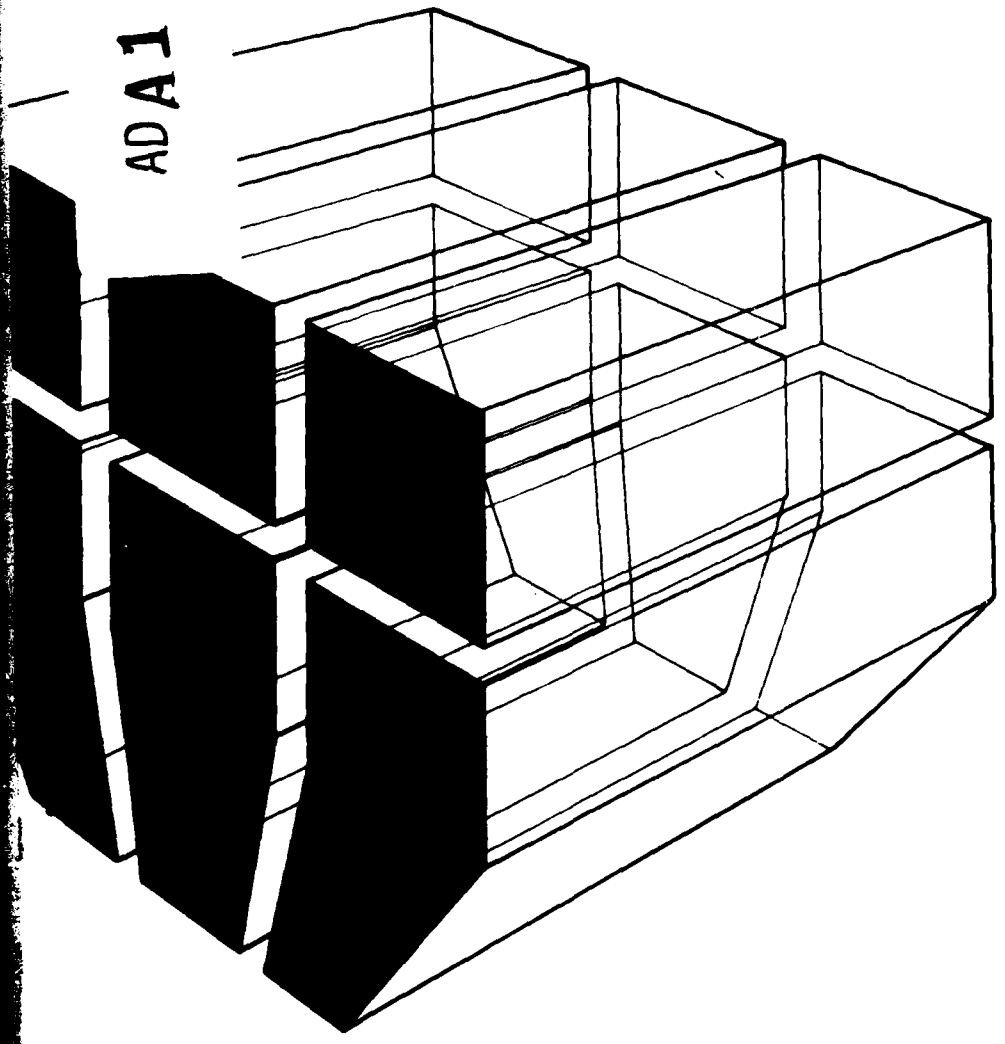
FORT IRWIN HOUSING COMPARISON TEST



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Congress has directed the construction of 200 units of manufactured/factory-built housing at Fort Irwin, CA, to see whether this method of construction will cost less than conventional housing, yet still provide durable housing commensurate with contemporary housing standards.

Congress has directed the Department of Defense (DOD) to conduct a fair and reliable study that will compare the operations and maintenance (O&M)

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costs of manufactured housing to those of conventional housing. DOD will report to Congressional committees on the conditions and parameters under which this test will be conducted and the results of the test, after it is completed.

To compare these two types of construction properly, DOD must be able to identify O&M costs and user satisfaction reliably. In addition, it must be able to identify differences in O&M costs and the reasons for those differences.

To address these issues, this report establishes the cost comparisons and analyses which must be done in the study, defines the cost and demographic data which must be collected, and identifies appropriate data collection procedures.

FOREWORD

This research was conducted for the Assistant Chief of Engineers, Office of the Chief of Engineers (OCE) under FAD No. 2-2427, dated 4 May 1982. The OCE Technical Monitor was Mr. Louis Layton, DAEN-ZCH-F.

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (CERL), Champaign, IL. The Principal Investigator was Mr. Michael J. O'Connor. Assistance was provided by Mr. Robert Blackmon, Dr. Douglas C. Hittle, Mr. Thomas Napier, and Mr. Robert Neathammer. Mr. E. A. Lotz is Chief of FS.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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FORT IRWIN HOUSING COMPARISON TEST

1 INTRODUCTION

Background

Congress believes that use of factory-built military housing, rather than conventionally built units, will result in lower overall costs, but still provide durable housing that meets contemporary housing standards. Therefore, Congress has directed the Department of Defense (DOD) to construct 200 units of manufactured housing at Fort Irwin, CA, to compare factory-built with conventionally built housing.

The manufactured units will be constructed to appropriate DOD standards and necessary criteria for essential space, structural durability, energy efficiency, material quality, and life safety. These standards and criteria will be compatible with, and complementary to, the Federal Manufactured Housing Construction and Safety Standards (FMHCSS). The Fort Irwin study will compare the impact of the FMHCSS versus standard DOD criteria, except for the essential criteria listed above.

The study will be conducted during the first 5 years that the housing units are occupied; initial occupancy is currently scheduled for July 1983. The study will compare 200 two-bedroom manufactured units to 124 two-bedroom, four-plex/two-story, single-family, conventionally built units. DOD will present the conditions and parameters of this test to Congress and will report the study results at the end of each year of the test.

To make proper comparisons of manufactured versus conventional housing, the study must address operation and maintenance (O&M) costs and user satisfaction for both types of housing. The study should not only identify the differences, if any, in O&M costs, but also identify why there are differences and the importance of those differences for future construction criteria, construction methods, and customer satisfaction.

Objective

The objective of this report is to define a methodology for collecting and analyzing O&M costs for both manufactured and conventionally built housing to support a fair and reliable comparison of both types of housing at Fort Irwin.

Scope

The total study of the manufactured housing concept includes initial construction costs, O&M costs, and user satisfaction. This report addresses O&M costs.

Approach

The cost comparisons and analyses which should be done in this type of study were established (Chapter 2). Then the cost, energy consumption, and demographic data which should be collected were defined (Chapter 3). Finally, data collection procedures were established (Chapter 4).

2 O&M COST AND ENERGY CONSUMPTION COMPARISON AND ANALYSIS

O&M Costs

The cost comparison and analysis is designed to answer the following questions regarding manufactured versus conventionally built housing:

1. Are the average annual O&M costs significantly different?
2. Where are the costs significantly different?
3. Why do the costs differ?
4. What criteria, design features, etc., need to be changed as a result?

Figure 1 is a summary report designed to partially answer the first two questions. The average maintenance and repair (M&R) cost per housing unit and the average utility cost per unit will be computed and totaled to give the total O&M cost per unit. A statistical test, such as the t-test, will be used to compare the O&M costs per unit for the two methods of construction. If the O&M costs are significantly different at the 99 percent confidence level and if the difference is of practical importance, then one construction method will have been proved to be more economical to operate and maintain than the other.

O&M COST SUMMARY

Average Annual Costs	Manufactured	Conventional	Difference
M&R Cost	XXX	XXX	XX
Utilities Cost	XXX	XXX	XX
*Carryover Cost	XXX	XXX	XX
Total O&M Cost/Unit	XXX	XXX	XX

*Carryover costs, to be included in the fifth year only, represent the cost required to restore both types of housing to a comparable level of "like new plus fair wear and tear."

Figure 1. O&M cost summary.

M&R and utility costs for each method of construction should be compared separately. If a significant difference in O&M cost is found, it is important to determine what is causing the difference. Even if no difference is found in the total O&M cost, the M&R and utility costs should be compared separately, since differences in M&R and utility costs may cancel each other in the total O&M cost.

In addition to the summary comparison, the M&R costs for major building components should be compared. Figure 2 lists the applicable major building components as defined in the Integrated Facility System (IFS). Such a comparison fully identifies where cost differences occur and begins to show why the costs differ. These comparisons should also be based on a formal statistical test at an appropriate confidence level.

For major components which show a statistically significant difference between the two types of construction, the analysis should be continued to the subcomponent level. The Appendix lists the applicable building components and subcomponents. This more detailed analysis shows why the costs are different. The reasons for cost differences can be determined only after the differences are identified at the subcomponent level.

M&R cost differences can be attributed to four basic causes:

1. Material Quality. Materials or products may differ in quality independent of any inherent differences in the two types of construction. For example, inferior flooring or kitchen cabinets will give a poor service life whether they are installed in a site-built or a manufactured home.

		Manufactured	Conventional	Difference
01	Roofing	xx	xx	x
02	Structure	xx	xx	x
03	Floor Coverings	xx	xx	x
04	Interior Painting	xx	xx	x
05	Exterior Painting	xx	xx	x
06	Heating	xx	xx	x
07	Air Conditioning	xx	xx	x
08	Plumbing	xx	xx	x
09	Electrical	xx	xx	x
10	Equipment	xx	xx	x
12	Utility Service	xx	xx	x
	Total	xxx	xxx	xx

Figure 2. Major building components.

2. Installation. Quality of installation or fabrication may differ for materials or products of equal quality, independent of the construction type. For example, poor installation of even top-quality roofing materials will cause either site-built or manufactured homes to be susceptible to roof leaks.

3. Inherent Differences. Design, engineering, materials, or installation methods can differ in ways inherent to either site-built or manufactured construction, or to the standards and practices that each employs. Examples include achieving tolerances in field or in-plant fabrication, or dimensional considerations due to transportation constraints.

4. Project Requirements. Differences could result from errors in specifications for a particular project. Specifying a particular material or technique may be inappropriate for a particular application, regardless of whether the home is site-built or manufactured.

If the Corps of Engineers is to take full advantage of both segments of the construction industry, the potentials and limitations of each segment must be known. If the reasons for cost differences can be identified and deficiencies easily corrected, then the Corps has another resource at its disposal. If the deficiencies cannot be corrected, then this study will demonstrate inherent limitations in a segment of the construction industry.

Energy Consumption

Monthly consumption of energy for heating, air conditioning, and hot water/appliances will be computed from electric and gas meter readings for each of the 324 housing units. Statistical tests will be conducted to determine if energy consumption, either total or by type of energy use, differs between manufactured and conventionally constructed housing.

However, this analysis will not identify the cause of the difference. For example, a difference in air-conditioning energy consumption can result from a difference in the housing unit's solar design or from a difference in the air-conditioning system's performance and efficiency. Therefore, a "whole house" performance test should be conducted on four or five housing units of each construction method.

The "whole house" performance test measures (1) the overall U-factor, (2) air infiltration rates, and (3) in-situ furnace efficiency. The "whole house" performance test, which requires only a few days to complete, must be conducted while the house is vacant, and during cool weather. During the test, the house is alternately heated by portable electric resistance heaters and the house furnace in a prescribed manner which allows both the overall U-factor and the furnace efficiency to be determined. Fans are used to pressurize the house, and air flow is measured to determine air infiltration rates. A series of two tests -- one before initial occupancy and the other several years later -- should be done to determine the effects of use and age on energy-related equipment and building components.

Assumptions for Analysis

For comparisons of O&M costs and energy consumption to be meaningful, the costs must be comparable. The purpose of the comparisons is to determine differences between manufactured and conventionally constructed housing. Any other variables that can cause differences must either be controlled so that they affect both methods of construction in the same way or their effects removed from the data before it is compared.

Duration of occupancy will be particularly significant during the first year, when the occupancy rate will be partially dictated by the construction schedule. Hence, the cost data must be normalized to reflect the average annual cost per unit for either a full or a typical occupancy rate. The costs must also reflect the same level of maintenance. Therefore, the cost to restore the units to a comparable level of "new plus fair wear and tear" must be included at the end of the study. Because of the different configurations of the manufactured and the conventionally built single-unit versus four-plexes, the O&M costs associated with the common areas and shared walls of the four-plexes should be prorated to each unit.

To insure comparability, the following assumptions have been made:

1. Construction "punch list" deficiencies will be corrected to the same extent for both methods of construction.

2. Warranties will be enforced equally for both types of housing.

3. Both types of housing will be maintained by the same organization (either by the Facilities Engineer [FE] or by contract).

4. Both types will receive equal attention, including preventive maintenance.

5. M&R will be done as needed to avoid unnecessary consequential damage.

6. The same grade personnel (Officer or Enlisted) will be assigned to both types of housing.

7. Housing for families within the same grade will be assigned randomly.

8. Both types of housing units will be exposed to equivalent weather and siting conditions.

9. A comparable amount of self-help will be done for both types of housing.

To guarantee that meaningful comparisons are made and valid conclusions are drawn, the above effects must be controlled to insure that these assumptions are met.

3 DATA TO BE COLLECTED

M&R Data

The M&R costs for each of the 324 housing units should be collected at the building subcomponent level. These costs include in-house FE costs and contract costs (for example, contract painting).

A copy of all maintenance documents, service orders, individual job orders, contracts, etc., should be filed separately.

Energy Data

Both gas and electricity should be metered individually for each unit. The meters should be read monthly and separate records maintained for these units. Annual energy costs should be calculated for the 200 manufactured and 124 conventionally built housing units, using the total annual energy consumption and the average cost per unit of each type of energy.

Demographic Data

Records of all housing assignments and terminations should be collected for each unit so that the duration of occupancy can be calculated. The number of family members and their ages should also be recorded. This will allow the assumption of random assignments to be verified and may also be required to normalize the energy consumption data.

4 DATA COLLECTION PROCEDURES

Figure 3 shows the data collection procedures. The FE should collect data for the comparison in accordance with standard operating procedures, with the following exceptions.

1. Workmen completing a Service Order/Individual Job Order (SO/IJO) on a test unit should revise the work description to reflect the work accomplished, describing actions taken, items installed, and causes, if known.

2. As SO/IJOs are processed, they should be annotated to indicate total costs, including overhead (OH), labor, and supplies.

Annotated SO/IJOs should be coded to the subcomponent level; documents with incomplete/unclear descriptions or data should be returned to the shops for clarification.

Annual cost of utilities for each housing unit should be calculated from meter data and utility contracts.

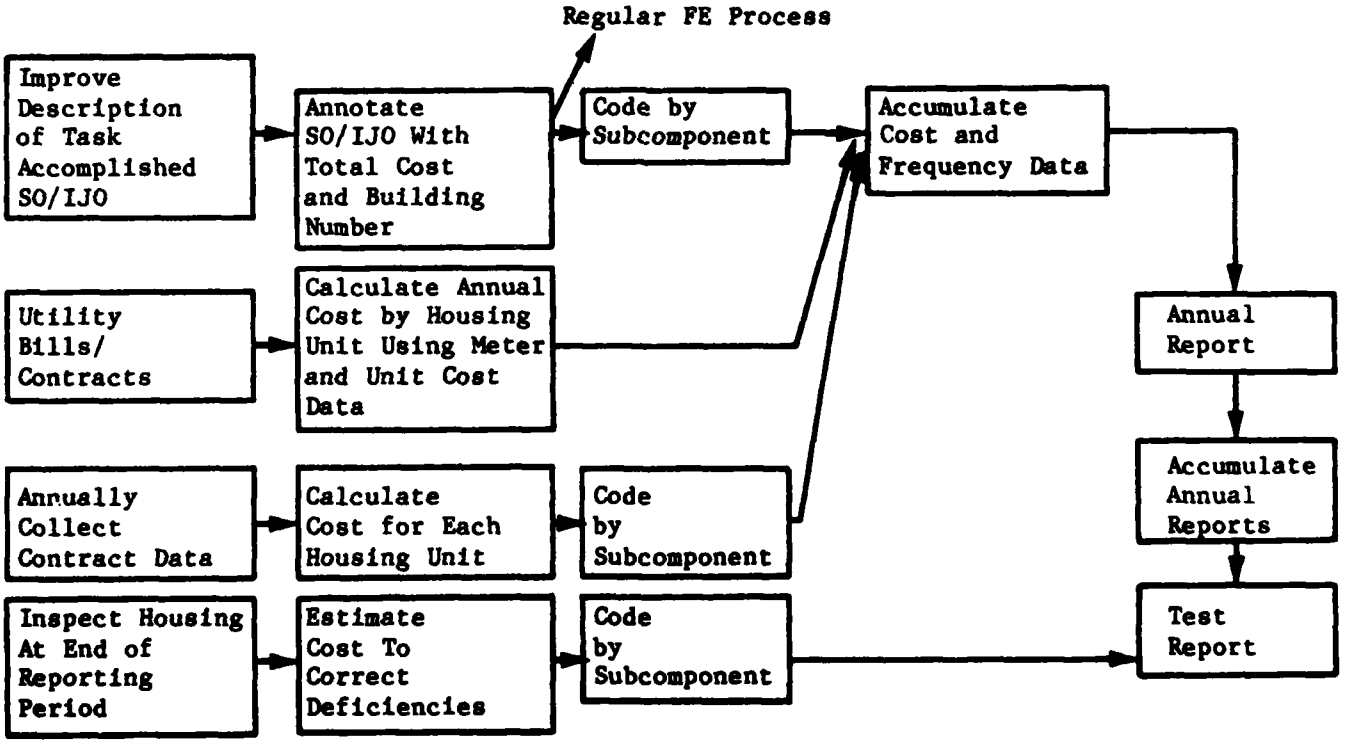

Figure 3. Data collection procedures.

Contract data should be broken down by housing unit and by subcomponent.

At the end of the test period, each housing unit should be inspected to determine M&R required to restore the unit to "like new plus wear and tear." A cost estimate to correct deficiencies should be prepared and included in the data recorded for each housing unit by subcomponent.

5 CONCLUSIONS

The results of the research indicate that:

1. M&R and utility costs should be compared separately.

2. M&R costs should be compared for each major building component.

3. Major components which show statistically significant differences should be compared on the subcomponent level.

4. Energy consumption should be computed from electric and gas meter readings for each housing unit.

5. A "whole house" performance test should be conducted on four or five housing units of each construction type to identify any causes of energy consumption differences.

6. Cost data should be normalized to reflect average annual cost per unit.

7. A copy of all maintenance documents, service orders, etc., should be kept and filed.

8. Records of all housing assignments and terminations should be collected for each unit.

9. With a few exceptions, data for the test should be collected in accordance with standard operating procedures.

6 RECOMMENDATIONS

It is recommended that:

1. The Fort Irwin FE be tasked to collect the O&M data as specified in this report. This could be accomplished by either modifying the existing Base Operations contract, by developing a new contract, or by temporary hire of FE personnel.

2. FORSCOM be tasked to perform the analysis of the O&M costs. This analysis could be done by FORSCOM or FORSCOM could fund CERL or some other activity to perform the cost analysis. The data, monthly meter readings, and annotated SO/IJO's, etc., should be forwarded to the analysis activity on a monthly basis for review and preliminary analysis to ensure data integrity. The O&M cost analysis should be performed and reported on a quarterly basis.

APPENDIX: Building Components/Subcomponents

01 ROOFING

0101 Roofing Surface
0102 Fasteners
0103 Flashing, Vents, Protrusions
0104 Gutters and Downspouts
0105 Other Roof Repair

02 STRUCTURE

0201 Foundation and Anchorage
0202 Structure, Incl. Framing and Sheathing, Stairs
0203 Insulation and Moisture Protection
0204 Masonry
0205 Exterior Siding, Incl. Skirting
0206 Exterior Doors and Frames, Incl. Hardware and Weatherstripping
0207 Storm and Screen Doors
0208 Windows and Frames, Incl. Hardware and Weatherstripping
0209 Stormwindows and Screens
0210 Exterior Trim
0211 Porch/Deck Construction
0212 Interior Drywall, Incl. Fasteners and Accessories
0213 Wall Coverings and Paneling
0214 Interior Doors, Frames, and Hardware, Incl. Bi-Fold and Sliding
0215 Interior Casework and Finish Carpentry
0216 Bathroom Accessories
0217 Kitchen Accessories
0218 Drapery Hardware
0219 Other Exterior/Interior Repair

03 FLOOR COVERINGS

0301 Resilient Flooring
0302 Carpet and Pad
0303 Ceramic Flooring
0304 Underlayment/Substrate
0305 Other Flooring Repairs

04 INTERIOR PAINTING

0401 Walls and Ceilings, Incl. Patching
0402 Trim
0403 Touch-Up
0404 Bath Tub/Shower Unit Calking
0405 Other Interior Painting

05 EXTERIOR PAINTING

0501 Walls, Siding, Incl. Skirting
0502 Doors, Frames, Trim
0503 Exterior Trim, Incl. Window, Fascia, Rake, Soffit, Etc.
0504 Caulking and Sealing
0505 Glazing
0506 Other Exterior Painting

06 HEATING

0601 Heating Plant
0602 Motors, Blowers, Pumps
0603 Ducts
0604 Piping
0605 Diffusers, Grills
0606 Insulation
0607 Heating Controls
0608 Other Heating Repairs

07 AIR CONDITIONING

0701 Cooling Coils, Compressor, Condensor
0702 Motors, Blowers, Pumps
0703 Piping
0704 Refrigerant
0705 Insulation
0706 Controls
0707 Other Cooling Repairs

08 PLUMBING

0801 Water Heater
0802 Water Softener
0803 Piping, Supply, Incl. Valves, Arrestors
0804 Faucets and Shower Heads
0805 Lavatories, Incl. Support and Fasteners
0806 Water Closets, Incl. Seals and Supports
0807 Bath Tub/Shower Unit
0808 Drain-Waste-Vent, Incl. Traps and Cleanouts
0809 Other Plumbing Repair

09 ELECTRICAL

0901 Service Entrance
0902 Panel Box, Incl. Circuit Breakers
0903 Branch Circuits, Incl. Junctions, Fasteners
0904 Wall Receptacles and Switches
0905 Doorbells, Chimes
0906 Light Fixtures

0907 Vents, Fans
0908 Other Electrical Repair

10 EQUIPMENT

1001 Disposal
1002 Dishwasher
1003 Stove, Range
1004 Range Hood
1005 Refrigerator
1006 Other Equipment

11 UTILITY PLANT EQUIPMENT

Not Applicable

12 UTILITY SERVICE

1201 Water Supply
1202 Gas Supply
1203 Electrical Service
1204 Sanitary/Sewer
1205 Other Utility Service

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